Acts and Knowledge Management in the NUCLEUS Hospital Information System

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NUCLEUS is a project completed in June 1995 in the frame of the European Community programme AIM (Advanced Informatics in Medicine). The main result of NUCLEUS is a prototype of an integrated patient dossier. Together with this patient dossier, facilities have been developed for its customisation by the various categories of end-users. A semantic model has been designed to guide and control the exploitation of data, and ensures the overall integrity of the information system.

INTRODUCTION

The main purpose of the project RICHE (Esprit project n° 2221) was to build a framework for open information and communication systems for health care in Europe and to demonstrate the feasibility of this evolutionary approach.[1,2] The mission of NUCLEUS (AIM project n° 2025) was to develop a working prototype of the main components and functions of a system that implements a multimedia integrated patient dossier and its associated customisation environment on the basis of an intelligent act management, as part of a RICHE consistent hospital information system.[3]

The conformance to the RICHE reference architecture provides NUCLEUS with major characteristics which are now recognised as mandatory in modern hospital information systems[4]:

- *integration*: to provide the various specific applications with a homogeneous management of data and communication facilities;
- *openness*: to accommodate existing as well as new applications, to ensure vendor-independence and to make it possible a progressive evolution of the information system;
- *customisation*: to support the great variety of exploitation conditions of the structure of the hospital, of medical specialities, of health care professionals personal practice, etc.

NUCLEUS promotes the patient dossier as a central element of the care process. The general approach relies on the concept of *act* associated to the requester-performer paradigm, and on the semantic model which exploitation ensures the overall integrity of the information system. The following sections present the authors' contribution to the project: semantic model, acts amangement, integrated patient dossier, and associated customisation facilities.

SEMANTIC MODEL

As an information system, NUCLEUS is built around the modelling of domain objects. This model identifies the set of objects which belong to the professional universe under consideration, here the hospital, describes their structure and defines the relationships which hold between them. The NUCLEUS model is object-oriented, built from classes and semantic relationships at two levels of abstraction, plus a data level.[5] This organisation is illustrated by the drawing of figure 1. A conceptual level defines each basic concept and relationship of the hospital universe and associates it with a class model (resp. relationship model). A semantic level identifies meaningful classes (classes of acts, of diseases, of diagnostic procedures, ...) organised in taxonomies and semantic relationships (such as "treats" from act to disease). The semantic level objects are instances of conceptual level objects. The data level, made of actual acts and associative links, is nothing but the actual content of the patient dossier.

The conceptual level is independent of the actual hospital under consideration. The semantic level is *evolutionary* (from a common kernel customised along various axes) and *active* as it can be activated and exploited at run-time by the application modules. This features helps to preserve the consistency and to interpret correctly the content of the patient dossier.

ACTS MANAGEMENT

Act is the central concept in NUCLEUS. An act is any professional activity which influences the

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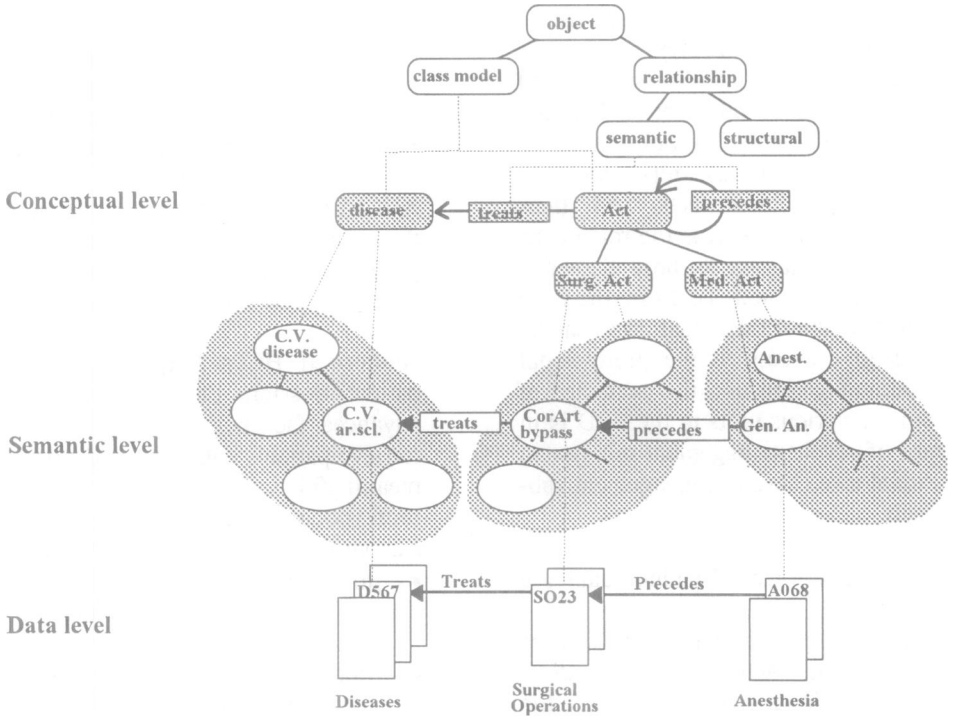
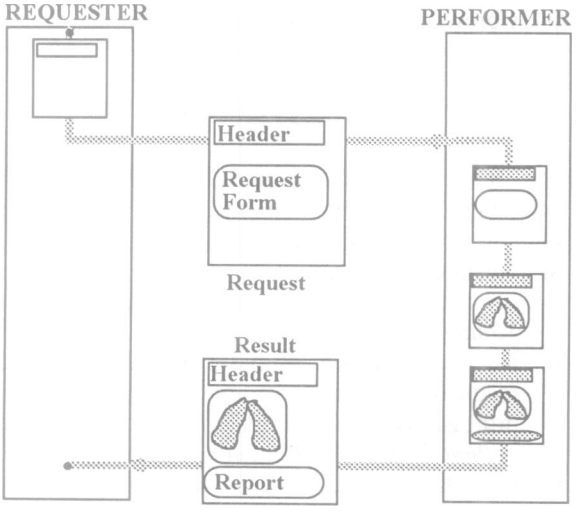
Figure 1: Structure of the semantic model



patient status or augments the knowledge about the patient status. Acts have life-cycles which are materialised by successive status's: established, requested, accepted, performed, reported, etc. An act header contains the current status value of an act together with administrative data necessary to its management (e.g., patient identifier, requester identifier, requesting unit, performing unit, etc).

Figure 2: The requester-performer paradigm



The medical information is carried by the *act professional content*. An act may be elementary, compound, or repetitive. In the two later cases, the act is decomposed into its component acts.

Acts management materialises the relationships between the requester/performer roles and provides the basis for the communication of professional information between applications, actors, care units and points of service inside the hospital and with the outside world. Figure 2 summarises the life-cycle of an act according to the requester-performer paradigm.

PATIENT REFERENCE DOSSIER

A major result of NUCLEUS is the definition and management of a patient dossier in terms of content, structure, and access to the information. The NUCLEUS patient dossier for a single patient is designed to contain all recorded data on the past, present and planned health situation. The actual content of the patient dossier is made of :

- medical information consisting of actual acts and the associated professional contents;
- associative links between actual acts as a means to structure and organise the patient dossier.

Both categories of patient dossier elements are instances of objects of the semantic model and constitute what we called the patient reference dossier (PRD). This close dependency ensures the integrity of the patient dossier and allows a safe and consistent communication of information between health care professionals. All this information is usually spread among the various units which are responsible of the individual acts and their associated professional contents. It is the role of the PRD to provide a unique access to those elements, from any location in the hospital. To do so, the PRD gathers in a central database the actual acts headers which themselves give access to the professional contents. The communication and the exchange of information from the various units to the PRD is in charge of the acts life-cycle management sub-system and the professional acts contents management sub-system respectively.

The organisation and storage of patient data are organised as follows:

- a local database in each unit provides storage facilities and management of medical information (professional content) related to the acts which the unit is responsible for (as requester or performer). This database is fed by the act management services allocated to each unit.
- the PRD database contains the information necessary for the management and the retrieval of acts in the whole hospital network, as well as references to the professional contents above mentioned. This database contains also the description of associative links set between acts.

This organisation of data allows to deal with the huge amounts of information represented by the professional contents locally associated with acts, while preserving a centralised management of references to those acts which allows efficient retrieval in the information system.

CUSTOMISATION

Acts are performed by health care professionals (HCPs) who need facilities to specify which acts they can perform, under what circumstances, and how these acts will be represented in the patient dossier. The *performer act customisation* facilities provide the responsible HCPs with the means to express the system's knowledge on the activities that can be performed, according to their respective professional paradigms.[6] This is the aim of the performer act customisation which provides facilities:

- to adapt the knowledge about classes of acts. It consists in the refinement of parts of the semantic model by the design of knowledge bases linked to the considered hospital unit;
- to define, adapt and relate the recording of patient dossier data to a particular act;
- to define and associate forms to the particular status of a particular act.

NUCLEUS exploits the form metaphor, by creating them as repositories of significant pieces of professional information, together with links with other data and with typical methods to treat them.

Authorised HCPs frequently need to access the patient dossier. For this purpose, they require advanced facilities to access the acts contents, to retrieve patients data, and to display these data in a meaningful way according to their own views and professional paradigms. This is the basis of *access customisation* which provides facilities :

- to structure the dossier by installing links connecting acts as elements of the patient dossier;
- to define and adapt specific views which allow to select, retrieve and present patient data.

The installation of associative links as well as the definition of views, in order to facilitate the navigation in the integrated patient dossier, are governed by the semantic model. In particular, associative links set between actual acts are instances of semantic links set between classes of acts at the model level.

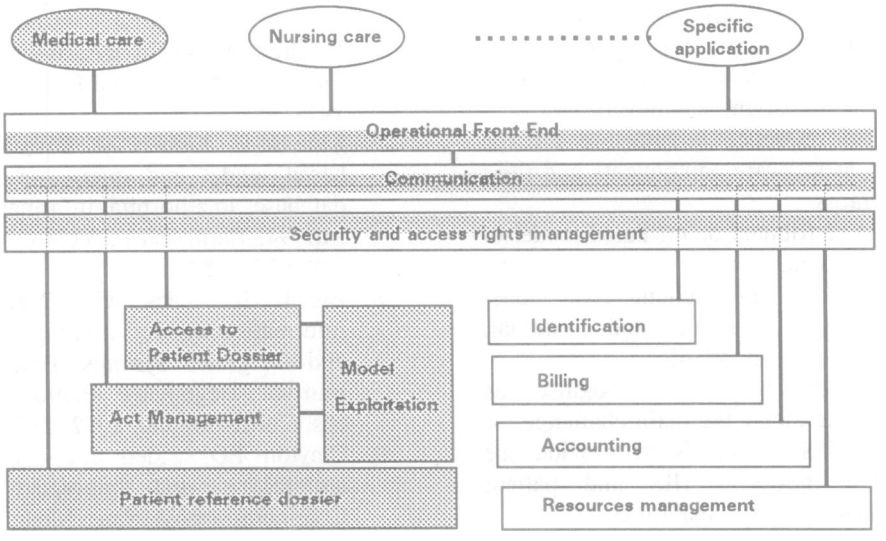
Access customisation is performed by using a dedicated querying language: XQL which provides enhanced information retrieval capabilities through direct access and navigation.[7] XQL includes requests to knowledge (to query/browse the semantic model) and requests to data (to query/browse the patient dossier).

ARCHITECTURE

The functional architecture has been designed following the requirements and needs from users, and in conformity with the RICHE Reference Architecture. That is:

- act as the central concept: functional block *Act Management*.
- the patient dossier as the privileged source of medical information for the health-care professional: functional blocks *Access to patient dossier* and *Patient reference dossier*.
- exploitation of the domain semantics: functional block *Model exploitation*.

Figure 3: Overview of the functional architecture



The three sets of services above form together the kernel of the functional architecture. On top of this kernel are:

- the *Operational front-end* which provides access to the kernel services.
- the *Communication layer* through which all exchanges of information are passing, subject to the corresponding access rights controls.
- a series of *End-user applications*, dedicated to a specific speciality or function in the hospital.

The diagram in figure 3 shows the functional architecture, which relies on the client-server model. Greyed areas shows the servers available from NUCLEUS.

IMPLEMENTATION

The exploitation architecture is built around a local network at the unit level, communicating with a central machine. Each local network is provided with a local server operated under UNIX (as for the central server) and PC/WINDOWS workstations. The technologies involved are ORACLE as databases management system, AIRS as documentary databases server, C/C++ as programming language and Visual C++ for user interfaces. The semantic model is implemented by proprietary tools relying on the notion of knowledge servers. Distribution facilities are provided by TUXEDO although a TCP/IP version is also available.

A working prototype of the system has been implemented on real user pilot sites. It is experimented in a general surgery ward at the Policlinico Gemelli hospital in Rome (Italy), the liver transplant unit of the Freeman Hospital in Newcastle (UK), and the obstetrics and maternity unit of the West Middlesex University Hospital in Isleworth (UK). These pilot implementations would provide feedback on the validity and practical applicability of the NUCLEUS solution.

DISCUSSION

The design and realisation of open hospital information system (HIS) is of central importance today.[1,2,4] An open and homogeneous environment shows many advantages but the necessity to use already purchased HIS components introduces heterogeneity.[8] Therefore, a main challenge is to integrate or, at least, to interface existing applications. Typical implementations of HIS use a central patient database with a common interface for the integration of various applications.[9] On the contrary, openness offers the natural support to distribution of data and services. It is therefore necessary to conceptualise an open HIS from both the computer science and the application perspectives.[10] The results have to be measured from both the organisational and financial point of view[11,12] and from the end-users side (costs and benefits).[13,14]

The requirements for the HIS to ensure integration, openness and customisation facilities have been stressed as short-term recommendations issued from a working conference organised by the International

Medical Informatics Association.[15] Among them, some are very close to the NUCLEUS perspectives:

- a modular architecture with a comprehensive model of the domain encompassing the professional environment of the health care professional and a patient data model.
- adoption of a reference architecture for the specification of software components and their mutual interfaces.
- adoption of a distributed or mediated model of knowledge and data.
- promotion of a distributed, client-server model calling for open systems and national, international de-facto standards.

Such recommendations have been recognised as mandatory in order to tackle the main challenge for the evolution of HIS, which is to provide the professionals with powerful HIS and patient medical dossier management capabilities.

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